RESEARCH DEPARTMENT

Calculation of the field strength required for a television service, in the presence of co-channel interfering signals

Part 3: The computer programme

RESEARCH REPORT No. RA-12/3

UDC 621.391.812.8.
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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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Head of Research and Development

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Part 3: The Computer Programme

PREFACE

The report on 'Calculation of the Field Strength Required for a Television Service, in the Presence of Co-channel Interfering Signals' is in three parts, as follows:

Part 1: The assessment of a single interfering source

Part 2: Effect of multiple interfering sources

Part 3: The computer programme

Parts 1 and 2 deal with the theoretical background of the subject, and have been written as entities which can be read separately; for a full understanding of the work, however, the reader is advised to study Parts 1 and 2 together. Part 3 describes the form and flow diagram of the original computer programme to carry out the calculation processes described in Parts 1 and 2; recent improvements in detail and adaptations to a larger and faster computer have been made, but are not considered here.

Research Report No. RA-12/3

CALCULATION OF THE FIELD STRENGTH REQUIRED FOR A TELEVISION SERVICE, IN THE PRESENCE OF CO-CHANNEL INTERFERING SIGNALS

Part 3: The Computer Programme

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CALCULATION OF THE FIELD STRENGTH REQUIRED FOR A TELEVISION SERVICE, IN THE PRESENCE OF CO-CHANNEL INTERFERING SIGNALS

Part 3: The Computer Programme

SUMMARY

Parts 1 and 2, which have been issued separately, give the theory underlying the calculation processes which have been actually used in the BBC Research Department. Part 3, which follows, describes the original computer programme used for carrying them out.

1. GENERAL

Before describing the computer programme in detail, it is useful to state the stages of the calculation necessary for the determination of co-channel interference levels, and hence the protected field strength in the presence of multiple interfering sources.

For each receiving test point we first calculate the interference due to individual co-channel interfering signals, as described in Part 1[1] of this report. We then calculate the protected field strength in the presence of a single interfering signal, and finally the protected field strength in the presence of all the individual interfering signals taken together, as explained in Part 2[2] of this report. Throughout the report, field strengths and standard deviations are regarded as expressed in decibels.

The procedure is as follows:

(i) The receiving location to be examined is selected.

(ii) Co-channel sources are listed. Then, for each of these:

(iii) The distance to the test point and the bearings to and from the test point are found.

(iv) The carrier-offset relationship of the wanted and unwanted signals is derived and the resulting protection ratio found.

(v) The bearing from the test point to the wanted transmitter is compared with (iii) to produce a receiving aerial directivity allowance. This is combined with a polarization allowance (if any).

(vi) The e.r.p. of the unwanted source (in dB relative to 1 kW) is obtained.

(vii) The median field strength of the unwanted signal for an e.r.p. of 1kW is calculated, together with the time variation.

(viii) The four components resulting from (iv), (v), (vi) and (vii) are summed to produce the protected field strength.

(ix) The foregoing procedure is repeated for all unwanted sources.

(x) With the medians and standard deviations derived in (ix) a combined time-location distribution is produced for each unwanted source.

(xi) These are combined by multiplying probabilities at chosen field-strength levels.

(xii) The resulting distribution is divided into segments each approximating to a Normal distribution; the median and standard deviation in time-location for each segment are determined.

(xiii) For each of these segments a probability at the mid-field-strength level is derived by multiplying the probabilities due to location variation only.

(xiv) From (xii) and (xiii) the standard deviation in location variation only is calculated and the standard deviation in time deduced.

(xv) These are used to derive the 95% time 50% location, 95% time 70% location protected fields and the time percentage for which 70% location will be protected for field strengths of 70 dB and 80 dB(μV/m).

2. THE COMPUTER

The computer originally used for this programme was an Elliott 803B digital computer with a 8192-word core store, an automatic floating point unit and two film handlers.

Input and output are both effected by means of punched paper tape.

The films used are 35 mm magnetic films with a storage capacity of 4096 64-word blocks on each film. Each computer word has a fixed length of 39 binary digits (bits).

Recently the number of transmitters to be considered has been increasing rapidly, and the Elliott 803B computer is no longer adequate. The programme has therefore been adapted for an ICT 1905 – a much larger and faster machine with a 32,000-word store and eight magnetic-tape decks, having paper-tape input and output to a line printer. Considerable improvements in the detail of the calculation have been achieved, but these are not discussed here, since the principles used and objectives sought remain unchanged.

3. DATA STORAGE

It was realized that the amount of data to be stored, up to 85 numbers per transmitter and 39 numbers per test location with eventually some hundreds of transmitters and perhaps two thousand test locations, was far in excess of that which the working store could accommodate.

It was also felt that input of the required data on punched paper tape each time the programme was run, was undesirable. Because of this it was decided to use films to store the information.

Since the film block length is only 64 words, the information had to be 'packed'. This involves storing two or more numbers in one computer word. The transmitter information can then be fitted on to one film block as can each set of test location information.

One film (A) contains five separate types of information:

(i) Data for the coast-line grid
(ii) A decode table for (i)
(iii) Transmitter/ channel correspondence list
(iv) Transmitter details
(v) Transmitter and country names

A second film (B) contains the test location details.

A separate programme is provided for the storage of these items and provision has been made for three specific types of change (transmitter location, carrier offset and e.r.p.) to transmitter details which are already stored.

4. FLOW DIAGRAM

The objective of the programme is to carry out the calculations required for obtaining co-channel interference levels and hence the protected field strength by the methods described in Parts 1[1] and 2[2]. The text which follows includes further details of the calculations, where these are required for understanding how the programme achieves its objective.

The essence of the required technique is explained by means of a flow diagram (shown in Table 1). This flow diagram includes references to the text of Part 3, where fuller explanation is to be found.

There are two programmes involved in carrying out the calculation. The first programme, Table 1(a), assembles the required data from Films 'A' and 'B' on a temporary store film. This cuts down film search time during the calculation.

TABLE 1(a)

Data Preparation Programme

Ref.	Programme	Reference Section
1	Coast-line grid, Film A to temporary film store (T.F.S.)	4.1
2	Decode table, Film A to T.F.S.	4.2
3	Country names, Film A to T.F.S.	4.3
4	Read data tape	4.4
5	Channel-transmitter data appropriate to channel specified on data tape, Film A to T.F.S.	4.5
6	Transmitter names for channel, Film A to T.F.S.	4.3
7	Repeat, from 5, for all required channels	
8	Sort all transmitters into ascending numerical order	
9	Transmitter data checking for correct channel, Film A to T.F.S.	4.6
10	Repeat, from 9 for all required transmitters	
11	Sort all test locations into ascending order	
12	Replace Film A by Film B	
13	Test location data from Film B	4.7
14	Pack height and store in appropriate transmitter, to T.F.S.	
15	Pack angles and store in appropriate test location, to T.F.S.	
16	Repeat, from 13, for all required test locations	

TABLE 1(b)

C.C.I. Calculation Programme

Ref.	Programme	Reference Section
1	Read data tape	
2	Coast line grid, from temporary film store (T.F.S.)	
3	Decode table, from T.F.S.	
4	Country names, from T.F.S.	
5	Channel-transmitter data appropriate to required channel, from T.F.S.	
6	Transmitter names for required channel, from T.F.S.	
7	Transmitter data for service area from T.F.S.	
8	Check channel; if error – stop	
9	Unpack test location numbers	
10	Calculate convergence at transmitter site	4.8
11	Unpack test location heights	
12	Terrain angle data for all test locations, from T.F.S.	
13	Calculate bearings and distance between test location and wanted transmitter	4.9
14	Calculate path composition between test location and wanted transmitter	4.10
15	Calculate e.r.p. at appropriate bearing (using linear interpolation)	4.13
16	Calculate convergence at test location	
17	Unpack terrain angles at test location	
18	Calculate terrain angle at test location in direction of transmitter (using linear interpolation)	
19	Calculate terrain angle at transmitter in direction of test location	
20	Calculate 1% time and 10% time field strengths for the appropriate path	4.11
21	Calculate 50% time field strength and σ_T for wanted signal	4.12
22	Repeat, from 13, for all test locations	
23	Print offset of wanted transmitter	
24	Transmitter data for interfering transmitter, from T.F.S.	
25	Check channel; if error – stop	
26	Print offset	
27	Calculate offset allowance	4.14
28	Unpack terrain angles at transmitter	
29	Calculate bearings and distance and path composition between test location and interfering transmitter	
30	Calculate convergence at transmitter if in U.K.	
31	Calculate receiving aerial directivity factor including polarization allowance	4.15
32	Sum offset and receiving aerial factors	
33	Calculate e.r.p.	
34	Sum offset, receiving aerial and e.r.p. factors	
35	Calculate terrain angles at test location in direction of transmitter	
36	Calculate terrain angle at transmitter in direction of test location	
37	Calculate 1% time and 10% time field strengths for the appropriate path	
38	Calculate 50% time field strength and σ_T for interfering signal	
39	Calculate extra protection required for long-term interference	4.17
40	Derive protected median field strength	4.16
41	Calculate σ_T for required signal	
42	Repeat, from 29, for all test locations	
43	Repeat, from 24, for all interfering transmitters	
44	Calculate σ_{TL} for a test location	4.18
45	Repeat, from 44, for all interfering transmitters	
46	Calculate 50% location, 95% time protected field strength Calculate 70% location, 95% time protected field strength	4.18
47	Calculate % time protected for 70% locations and 70 dB protected field strength. Calculate % time protected for 70% locations and 80 dB protected field strength	
48	Calculate 95% time, 50% location protected field for an interfering transmitter	
49	Repeat, from 48, for all interfering transmitters	
50	Print out	Table 2
51	Repeat, from 44, for all test locations	
52	Repeat, from 7, for all wanted transmitters	
53	Repeat, from 5, for all channels	

The second programme, Table 1(b), describes the sequence of calculation showing the transfer of data from the temporary store film into the main store where required.

4.1. Coast-line Grid

The data for the coast-line grid consists of a series of distances in kilometres from the North Pole along lines of longitude, these lines being spaced at 0·1° intervals from 10°E to 10°W. There are thus 201 such lines, and the distances stored are those corresponding to land/sea intersections which occur along each line. To provide a known datum, i.e. that the first distance is a crossing from land to sea, a dummy coastline at 62°N is included. Since the number of intersections along each line varies from line to line, a decode table has been set up. The total number of intersections to be stored is about 1000. These are 'packed' two to a word and occupy 9 film blocks, not all of which are completely filled.

TX Site Name: ____________ No. ______/______ Date: ____________

N.G.R. ____________ or Lat. ___° ___' ___"N Long. ___° ___' ___"

UHF Ch. and Off.: ___/___ ___/___ ___/___ ___/___ ___/___ ___/___

V.H.F. Frequencies

Vision ____________ kc/s ____________ kc/s

Sound ____________ kc/s ____________ kc/s

____________ kc/s ____________ kc/s

Pol: H V

Terrain Clearance Angles for TX Ae.: ____________ feet (a.s.l.)

0°		10°		20°		30°		40°		50°	
60°		70°		80°		90°		100°		110°	
120°		130°		140°		150°		160°		170°	
180°		190°		200°		210°		220°		230°	
240°		250°		260°		270°		280°		290°	
300°		310°		320°		330°		340°		350°	

Rel. F.S. on Bearings East of True North for Unit Field ____________ kW

0° ______ 20° ______ 40° ______ 60° ______ 80° ______ 100° ______

120° ______ 140° ______ 160° ______ 180° ______ 200° ______ 220° ______

240° ______ 260° ______ 280° ______ 300° ______ 320° ______ 340° ______

Test Locations within the Service Area

No.	Name	No.	Name
1.		9.	
2.		10.	
3.		11.	
4.		12.	
5.		13.	
6.		14.	
7.		15.	
8.		16.	

Fig. 1 - Transmitter data sheet

4.2. Decode Table

The decode table gives, for each line, the position of the first element of that line in the coast-line grid and the number of intersections. These two items of information are 'packed' into one computer word, so the decode table occupies 201 locations. For convenience this is stored on film and occupies four blocks.

4.3. Country and Transmitter Names

Country names are stored in full. Transmitter names are abbreviated to a maximum of seven letters to facilitate storage in one computer word.

4.4. Data Tape

The data tape specifies:

(a) The number of channels to be considered

(b) For each channel in (a), the channel number, the number of the first United Kingdom transmitter to be dealt with (treating the transmitters on the channel as a set numbered in sequence), and the number of United Kingdom transmitters to be considered. If required, calculations can be carried out on a part of any sequence of transmitters occupying the same channel.

(c) The date

4.5. Transmitter/Channel Correspondence List

The correspondence list presently occupies one film block per channel. It consists of the number of United Kingdom transmitters, the number of continental transmitters and a list of these transmitters in the form of their code numbers.

This information is stored in a modified form in that the transmitter code numbers are replaced by the corresponding film block numbers. This is done by the storage programme. Channel N occupies film block N + 10.

4.6. Transmitter Data

Each United Kingdom transmitter has been given a pair of numbers. The first is the number of the main station and its service area, and this is at present in the range 101 – 164. The second is 0 for the main station and the relay stations in the area are then numbered in sequence. Provision has been made for 20 relay stations in the service area of each main station. Continental transmitters have been allocated a single number from 201 onwards with each country having a block allocation giving room to add extra transmitters when required. United Kingdom transmitters are stored in film blocks 100 – 1444 and continental transmitters in blocks 1501 – 3000.

The data for each station are provided on the forms shown in Fig. 1 and, with the exception of the offsets, the details are assumed to be the same for all the channels at each station. The essential information is:

(i) Transmitter number

(ii) Transmitter location, i.e. latitude and longitude. The storage programme provides for the location to be specified as a National Grid reference, if required, and contains a routine to convert this to latitude and longitude by the method laid down in an Ordnance Survey booklet.[3]

(iii) Channel numbers
(iv) Corresponding offsets
} Packed so that each pair occupies one computer word.

(v) Polarization

(vi) Height of transmitting aerial above mean sea level

(vii) Terrain clearance angles at transmitter at 10° intervals of azimuth 'packed' so that five occupy one computer word.

(viii) The horizontal radiation pattern of the transmitting aerial in terms of relative field strength at 20° intervals. This is converted to e.r.p. (dB relative to 1 kW) by the storage programme, and 'packed' so that six occupy one computer word.

(ix) The numbers of up to fourteen test receiving sites (for United Kingdom transmitters only).

All the above information is stored on one block of film (A).

4.7. Test Location Data

Each test location in the country has been allocated a number from 0 to 4095. This defines the block number of film (B) on which the data is stored.

The data consists of:

(i) Location i.e. latitude and longitude but specified as a National Grid reference if required (see Section 4.6.)

(ii) Height of receiving aerial above mean sea level assuming always a receiving aerial 9·1 m (30 ft) above ground level.

(iii) Terrain clearance angles at 10° intervals of azimuth.

4.8. Convergence

The 'convergence' is the angle between the north/south grid line and true north at any point.

4.9. Calculation of Distance and Bearings between two Locations

The calculation of distance and bearings between two locations is illustrated in Fig. 2(*a*). Let $(\theta_A \phi_A)$ $(\theta_B \phi_B)$ be the latitudes and longitudes of two points A and B, X be the bearing of B from A, Y be the bearing of A from B, and Z be the great circle distance AB. We have:

$$\tan \tfrac{1}{2}(Y+X) = -\cot \tfrac{1}{2}(\phi_B - \phi_A) \times \frac{\sin \tfrac{1}{2}(\theta_B - \theta_A)}{\cos \tfrac{1}{2}(\theta_B + \theta_A)}$$

$$\tan \tfrac{1}{2}(Y-X) = -\cot \tfrac{1}{2}(\phi_B - \phi_A) \times \frac{\cos \tfrac{1}{2}(\theta_B - \theta_A)}{\sin \tfrac{1}{2}(\theta_B + \theta_A)}$$

$$\tan \tfrac{1}{2}Z = \tan \tfrac{1}{2}(\theta_B - \theta_A) \times \frac{\sin \tfrac{1}{2}(Y-X)}{\sin \tfrac{1}{2}(Y+X)}$$

unless $\theta_B = \theta_A$ when

$$\tan \frac{Z}{2} = \cot \tfrac{1}{2}(\theta_B + \theta_A) \times \frac{\cos \tfrac{1}{2}(Y-X)}{\cos \tfrac{1}{2}(Y+X)}$$

If $\phi_A = \phi_B$ then $X = 0°$, $Y = 180°$ if $\theta_B > \theta_A$

or $X = 180°$, $Y = 0°$ if $\theta_B < \theta_A$

and $Z = |\theta_B - \theta_A| \times 111{\cdot}136$ km

The only places where these formulae can break down are:

$\theta_B + \theta_A = 0$, i.e. A, B in different hemispheres

or $\dfrac{\theta_B + \theta_A}{2} = 90°$, i.e. A, B at North Pole

Neither of these cases is relevant to the U.K. problem.

4.10. Calculation of Land and Sea Path Lengths

The 'bearing' of the test location from the North Pole is first determined, this being defined as the angle west of 10°E. Its distance from the Pole is found simply since it is along a line of longitude, i.e. the distance is 111·136 x (90° − latitude) km.* The 'bearing' and distance of the unwanted transmitter from the North Pole are determined in a similar manner. The bearings and distance between the unwanted transmitter and the test location are then calculated by the method described in Section 4.9.

The method of calculating the land and sea paths is illustrated in Fig. 2(*b*). The great circle path between the transmitter and the test location crosses a family of coastal grid-lines of which, for clarity, only two are shown in the figure. The programme now goes through, in sequence, each grid line which falls between the unwanted transmitter and the test location, starting with that nearest the transmitter. If no grid line is crossed between these two points, then the nearest grid line is taken to represent the composition of the propagation path. The distances along the line between

* (90° − latitude) is here expressed in degrees and decimals of a degree.

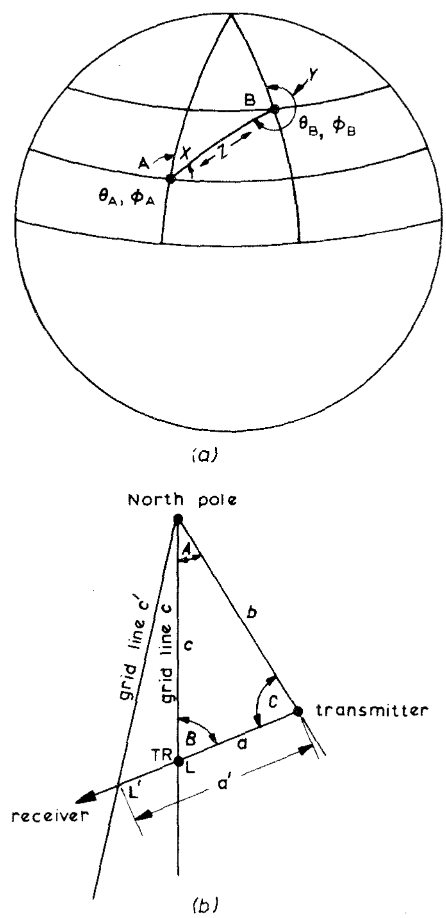

Fig. 2 - Calculation of distance and bearings between two locations

each coastal intersection between transmitter and test location are multiplied in the ratio of the true great circle distance to that which is projected on the grid line.

If the special case described above does not occur, the sequence illustrated by Fig. 2(*b*) is followed. The distance from the transmitter along path TR to the intersection with the first grid line (L) and the distance of L from the North Pole are calculated using the spherical triangle. If the triangle has angles A, B, C and the opposite sides are a, b, c expressed as angles subtended at the centre of the sphere, then:

$$\cot a . \sin b = \cos b . \cos C + \cot A . \sin C$$

In this case, side b, and the two angles A and C are known, so that a and similarly c are derived.

The process is repeated with the next grid line, resulting in distances c' and a'. The path between L and L′ is assumed to be represented by the portion of the grid line between distances c and c'. These land and sea dimensions are multiplied by $(a'-a)/(c'-c)$ to give the correct distance LL′. At the grid line immediately before the test location, the second point is the receiver instead of an intersection point. The result of the process described above is a series of distances from the transmitter along the path TR defining the coastal intersections. It is arranged so that both transmitter and test location are on land, i.e. there is an even number of intersections.

It was found when using this method that a false intersection at small intervals could be obtained when the path is parallel to the coast-line. For this reason, it was decided to regard as sea a stretch of land projecting into the sea but less than 5 km wide, and vice versa.

4.11. Field-Strength Calculation

The information required for the field-strength calculation (i.e. distance between transmitter and receiver, height and terrain clearance angle at transmitter and receiver, and path constitution in terms of land or sea), is now available.

The land-sea information is used to express the path constitution as a ratio of 'all sea', e.g. all land, 0; half and half, 0·5. The following calculation is now carried out for 1% time land, 10% time land and, if the land-sea fraction is not zero, for 1% time sea and 10% time sea.

The basic field strength F_b is considered in terms of free-space loss minus an urban loss. We then allow

(i) A loss F_1 increasing linearly with the distance between transmitter and receiver, with an additional loss F_2 introduced at the horizon if they are screened from each other by the curvature of the earth. The F_1 and F_2 losses depend on the path constitution, i.e. land or sea, and also on the percentage time for which the field is required (see Part 1[1] Section 3.2.)

(ii) A loss (F_0) depending on the terrain clearance angle within 15 km of the terminals

(iii) A gain (F_g) depending on the terrain clearance angle and the aerial height

The distance to the horizon can only be estimated approximately since mean land height is above sea level. For the purpose of this report, mean land height has been taken as 120 m above ordnance datum. This value of average land height is somewhat arbitrary, but the precise value does not affect the calculation to an important extent. Where the intervening path is sea, an horizon height of zero is used.

The sum of the horizon ranges (D_H) is then given by

$$D_H = (2R)^{1/2}\left\{(h'_T)^{1/2} + (h'_R)^{1/2}\right\}$$

where h'_T, h'_R are the heights of transmitter and receiver above the datum height (always $\geqslant 0$) and R is the radio radius of the earth; R is given values depending on the land-sea path ratio and also on the percentage time for which the field is required.

Because the terrain clearance angle takes into account details of the ground within 15 km of the site, complete profile information is available for path lengths between transmitter and receiver of up to 30 km.

Where the distance between transmitter and receiver is less than 30 km, or greater than 30 km

but within the horizon, the terrain clearance angles are redefined relative to the line joining transmitter to receiver, as shown in Figs. 3(*a*) and 3(*b*); these modified angles a_1 and a_2 are referred to as 'terrain correction angles.' This means a correction to the terrain clearance angle of θ_T degrees at the transmitter, where:

$$\theta_T = \left\{d/2R + (h_T - h_R)/d\right\}\left\{180/\pi\right\}$$

where d is transmitter-receiver distance, and θ_R degrees at the receiver where:

$$\theta_R = \left\{d/2R + (h_R - h_T)/d\right\}\left\{180/\pi\right\}$$

The angles θ_T, θ_R are those between the horizontal and the line-of-sight at the transmitter and receiver respectively. Thus, the terrain correction angle α_1 at the transmitter is given by

$$\alpha_1 = (\theta_1 - 90) - \theta_T$$

Similarly, at the receiver

$$\alpha_2 = (\theta_2 - 90) - \theta_R$$

If the distance is greater than that to the horizon, as in Fig. 3(*c*), the terrain correction angles are those relative to the line from aerial to the horizon. The correction angle θ_T degrees is given in this case by:

$$\theta_T = (2h_T/R)^{1/2}\left\{180/\pi\right\}$$

In order to make some allowance for ground clearance, the terrain correction angle has to be greater than 0·1326° for the path to be considered clear. This value was selected after investigating measurements and related factors, but is also consistent with first Fresnel zone clearance at the mid-point of a 30 km path for a frequency of about 1000 MHz.

If the path between transmitter and receiver is less than 15 km, and either α_1 or α_2 is greater than 0·1326° then there must be line-of-sight. The field strength is then F_b as defined above.

If neither terrain correction angle represents a clearance, then the linear loss F_1 is applied, together with the loss F_o shown in Fig. 4 defined by an angle α defined as follows:

$$\begin{array}{lll} \alpha = 0 & \text{if } \alpha_1 \geqslant 0 \text{ and } \alpha_2 \geqslant 0 \\ \alpha = \alpha_1 & \text{if } \alpha_1 < 0 \text{ and } \alpha_2 \geqslant 0 \\ \alpha = \alpha_2 & \text{if } \alpha_1 \geqslant 0 \text{ and } \alpha_2 < 0 \\ \alpha = \alpha_1 + \alpha_2 & \text{if } \alpha_1 < 0 \text{ and } \alpha_2 < 0 \end{array}$$

If the path length is between 15 km and 30 km, and both terrain correction angles represent a clearance then the field strength is the basic figure F_b. If either terrain correction angle is less than 0·1326° then the linear loss F_1 and the obstacle loss F_o for the angle equal to the sum of the negative terrain correction angles are applied to the basic field strength F_b.

If the path length is greater than 30 km, then the linear loss F_1 is applied together with the additional loss F_2 if transmitter and receiver are beyond the horizon from each other. At each terminal, if the terrain correction angle is less than 0·1326° then the terrain correction loss (F_o) is read off from Fig. 4.

Terrain correction gain is applied only to path lengths exceeding 30 km and is determined by the angles shown in Fig. 3(*d*). From each terminal we draw a line to the horizon if the path length equals or exceeds D_H, or to the other terminal if the path length is less than D_H. We also draw a line from the terminal to a point at the horizon height, at 15 km from the terminal; α_H is then defined as either the angle between these lines, or as 0·1326° if α_H is less than 0·1326°.

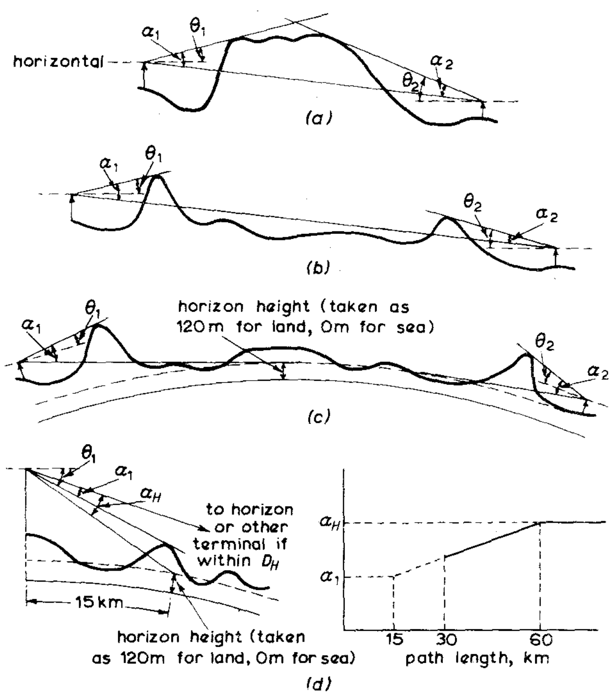

Fig. 3 - Path geometry diagrams

(*a*) Terrain correction loss; path length <30 km (a_1, a_2 are negative in this figure)
(*b*) Terrain correction loss; path length >30 km <D_H
(*c*) Terrain correction loss; path length >D_H
(*d*) Terrain correction gain; derivation of angles and interpolation (one terminal). (a_1, a_H are positive in this figure)

θ_1, θ_2 are terrain clearance angles
a_1, a_2 are terrain correction angles
D_H is the sum of horizon distances

For path lengths between 30 km and 60 km the angle used is a value obtained by a linear interpolation, as indicated in Fig. 3(*d*), between the terrain correction angle α_1 (or 0·1326° if α_1 is less than 0·1326°) and the value of α_H determined as described above.

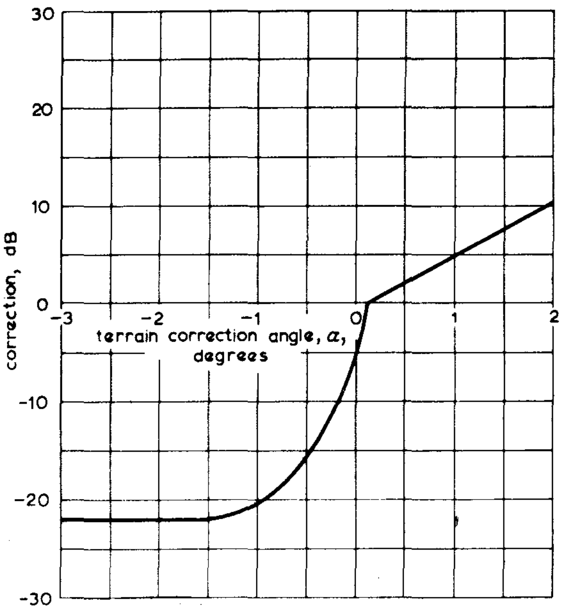

Fig. 4 - Terrain correction

The terrain correction gain is obtained from Fig. 4 for each end of the path, and the gains added.

Having calculated 1% time and 10% time field strengths for land, and if necessary for sea, the 1% time and 10% time figures for the appropriate mixed path are derived as proportions between all-land and all-sea.

4.12. Calculation of Median Field Strength and σ_T

Let the two median-location field strengths exceeded for 1% and 10% time be $E_{1,50}$ and $E_{10,50}$ respectively. Assuming a Normal distribution in time, the median value (M), and the standard deviation (σ_T) in time are calculated using equations:-

$$\sigma_T = 0{\cdot}9559\,(E_{1,50} - E_{10,50})$$
$$M = 2{\cdot}2259\,E_{10,50} - 1{\cdot}2259\,E_{1,50}$$

The σ'_T for the interfering signal level relative to the wanted signal level is calculated from the individual values σ_{TU} and σ_{TW} from the formula:-

$$\sigma'_T = \left\{\sigma^2_{TW} - 2\rho\sigma_{TU}\sigma_{TW} + \sigma^2_{TU}\right\}^{1/2}$$

assuming a coefficient of correlation (ρ) of 0·5.

Similarly σ'_L for the interfering signal level relative to the wanted signal level is calculated from

$$\sigma'_L = \left\{\sigma^2_{LW} - 2\rho\sigma_{LU}\sigma_{LW} + \sigma^2_{LU}\right\}^{1/2}$$

assuming a coefficient of correlation (ρ) of 0·5.

It is also assumed that σ_L for any signal is 5 dB hence σ'_L = 5 dB (See Part 2[2], section 4.3.).

4.13. Calculation of E.R.P. Factor

The e.r.p. term for the unwanted station in the direction of the test location is found using linear interpolation between the 20° values stored after 'unpacking.'

4.14. Carrier Frequency Offset Protection Ratio

Apart from nominal zero offsets the only offset conditions considered are ± 2/3 line-scan frequency.

The protection ratio required when there is an offset between wanted and unwanted signals is 30 dB.

The protection ratio required for no offset between wanted and unwanted signals is 45 dB.

4.15. Calculation of Receiving-Aerial Directivity Factor

The receiving-aerial directivity factor is a function of the difference in bearings of wanted and unwanted transmitters from the test location. The polarization of each transmitter is already available in the store, and an allowance is included in accordance with the information contained in Fig. 5.

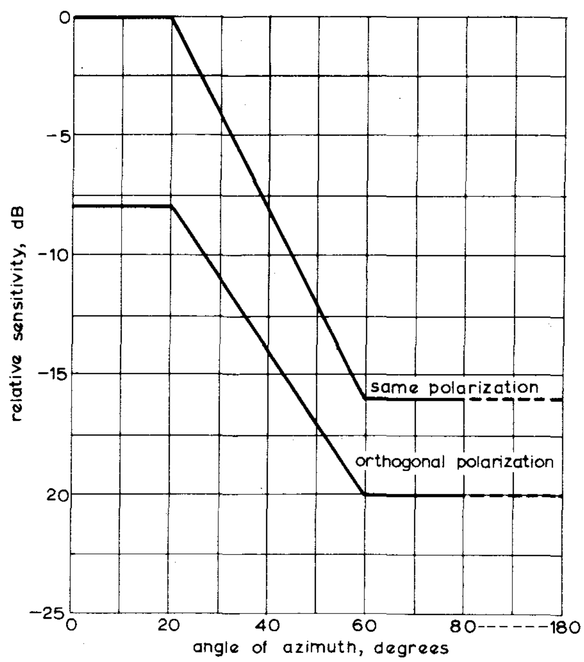

Fig. 5 - UHF receiving aerial discrimination curves
Angle relative to direction of main response

4.16. Median Protected Field Strength, M'

The median protected field strength (M')

= (median field strength, M) + (e.r.p. term)

+ (protection ratio for carrier frequency offset)

+ (receiving aerial directivity factor)

4.17. Extra Protection Ratio for Long-Term Interference

The 95% time protected field strength is calculated from the formula

$$E'_{95,50} = M' + 1{\cdot}645\sigma_T$$

If $(E'_{95,50} - M') < 10$ (i.e. $\sigma_T < 6{\cdot}1$) then the particular protected field strength is increased by the extra protection ratio $(10 - 1{\cdot}645\sigma_T)$ dB.

4.18. Multiple Interference Calculation

Since the two variables involved, time and location, are independent, the standard deviation σ'_{TL} of the field strength for a combined variable time-location, is given by

$$\sigma'^2_{TL} = \sigma'^2_T + \sigma'^2_L$$

The combined effect of many interfering sources is found in the following manner, with the object of determining the median field strength from the wanted station at the test location that gives a protection probability product in time-location of 95% ± 1%. An initial field strength of 70 dB is assumed and the probability of protection against each interfering source acting separately is found. The product of these probabilities is calculated giving the probability of protection with this field strength against all sources. In general this will not be the value of 95% ultimately required. A note is made of the σ'_{TL} of that source which affects the product to the greatest extent, i.e. the source whose probability of protection is least. The assumption is made that this σ'_{TL} is representative of the slope of the probability product curve at this field strength. It is then used to determine from the probability product for 70 dB the field strength for 95% probability of protection. This new estimate of the field strength required is now used to find a new probability product and the process repeated until a field strength is found which gives a probability product in time-location within 1% of the required value. If, when the third or subsequent value of field strength is found, the field-strength sequence is oscillating, i.e. $E'(n) - E'(n-1)$ has a different sign from $E'(n-1) - E'(n-2)$, a speeding up of the convergence is obtained if the next value of field strength used is $\frac{1}{2}[E'(n) + E'(n-1)]$ instead of $E'(n)$. If after six loops, the test is still not satisfied, then a linear interpolation based on the differences between the achieved and wanted probability products for two loops is used to derive the next value of field strength.

Having determined E'_{95}, the whole process is repeated for 90%, 82%, 70% and 56% probability products, giving E'_{95}, E'_{90}, E'_{82}, E'_{70}, E'_{56}. Each interval e.g. E'_{95} to E'_{90}, is considered in turn. The bounding field strengths are assumed to define a Normal distribution and since the probability products at these field strengths are known, the median M' and standard deviation σ'_{TL} for this distribution are found.

The mean field strength in the interval is taken and the probability of protection against each interfering source, when the variation of field strength *with location only* is considered, is found. The product of these probabilities is calculated and, together with the previously calculated median field strength, is used to derive σ'_L for the interval. This σ'_L is limited to a maximum of 5 dB. Hence, from σ'_{TL} and σ'_L, σ'_T is calculated. From the values of median and σ'_T, the field strength required to protect against interference for 95% time and 50% location is found. This is checked to see if it lies between those values of field strength used to define the interval. If it does not, the next interval is considered and so on.

Having found the interval such that the field strength required to protect for 95% time and 50% location lies within it, the field strength required to protect for 95% time and 70% location is calculated using the appropriate σ'_L and assuming this may still be referred to the parameters of the same interval.

The other information required is the percentages of time for which field strengths of 70 dB and 80 dB protect 70% of locations against interference. Again the interval into which the field strength falls is found, and the appropriate σ'_T are used to calculate the percentage of time.

A typical computer print out is shown in Table 2.

TABLE 2

Co-Channel Interference Calculation with Terrain Correction

Channel	Date	Service Area
26	2 / 9 / 66	C P

No.	Test Location Dist. (km) From TX	Bearing (Deg)	95% Time 50% Locn F.S. (dB) Prot.	95% Time 70% Locn F.S. (dB) Prot.	70% Locn 70 dB % Time Prot.	70% Locn 80 dB % Time Prot.
224	35·6	191·5	61·0	63·3	98·6	99·9

RELATIVE CONTRIBUTIONS

TX	50% Time 50% Locn F.S. (dB) Prot.	S.D. Time	95% Time 50% Locn F.S. (dB) Prot.	Aerial direct. (Deg)	TX Bearing (Deg)
Stratfd	14·5	6·0	24·3	303	314·6
Ramsbot	–14·5	13·9	8·3	321	332·9
Skipton	–33·2	15·4	–7·8	325	336·8
Halifax	–12·1	13·7	10·5	327	338·0
Swansea	–23·4	12·6	–2·7	271	282·6
Rhondda	–10·8	10·7	6·9	273	284·2
C Risca	21·4	8·8	35·9	273	284·8
Hexham	–55·5	20·5	–21·7	333	344·2
Cromer	13·2	10·1	29·8	13	24·2
Alburg	34·4	7·8	47·3	32	43·5
N Yorks	28·2	15·6	54·0	337	348·8
Wrekin	20·5	9·5	36·1	305	316·4
Stockld	36·7	8·0	49·9	249	260·3
Ayrshir	–60·3	26·2	–17·2	320	331·5
Banff	–91·7	36·3	–31·9	334	345·7
Lewis	–134·5	42·5	–64·6	322	333·5
Ireland					
Kippure	–12·0	25·8	30·5	288	299·5
Mulrany	–88·7	36·3	–28·9	287	298·6
S Naght	–86·9	33·9	–31·0	304	315·0
Germany					
Bonn	–61·2	25·4	–19·4	79	90·9
Fulda	–105·7	34·2	–49·4	79	90·0
Minden	–74·1	33·3	–19·3	62	73·6
Sleswig	–85·4	50·1	–2·9	44	55·2
Stutgat	–113·1	35·6	–54·5	95	106·1
France					
Besacon	–87·9	31·4	–36·2	118	129·8
Bourges	–35·0	24·3	5·1	140	151·9
Meziere	–3·3	18·9	27·7	99	110·5
Nancy	–58·6	26·2	–15·4	106	117·3
Nantes	–18·7	27·1	25·9	179	190·8
Rouen	25·4	14·3	48·9	143	154·5
Holland					
Lelstad	1·2	26·5	44·9	53	64·8
Belgium					
Molhout	–28·2	20·3	5·2	73	84·1
Norway					
Flo	–184·5	73·8	–62·9	4	15·8
Oevre	–132·0	63·8	–26·9	16	27·0

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